



CSE341: Programming Languages Lecture 5 More Datatypes and Pattern-Matching

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Useful examples

Let's fix the fact that our only example datatype so far was silly...

Enumerations, including carrying other data

Alternate ways of identifying real-world things/people

Don't do this

Unfortunately, bad training and languages that make one-of types inconvenient lead to common *bad style* where each-of types are used where one-of types are the right tool

```
(* use the studen_num and ignore other
  fields unless the student_num is ~1 *)
{ student_num : int,
  first : string,
  middle : string option,
  last : string }
```

- Approach gives up all the benefits of the language enforcing every value is one variant, you don't forget branches, etc.
- And makes it less clear what you are doing

That said...

But if instead the point is that every "person" in your program has a name and maybe a student number, then each-of is the way to go:

```
{ student_num : int option,
  first : string,
  middle : string option,
  last : string }
```

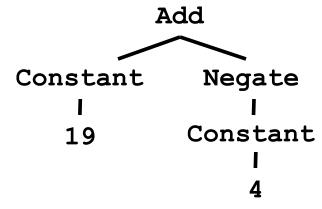
Expression Trees

A more exciting (?) example of a datatype, using self-reference

An expression in ML of type **exp**:

```
Add (Constant (10+9), Negate (Constant 4))
```

How to picture the resulting value in your head:



Recursion

Not surprising:

Functions over recursive datatypes are usually recursive

Putting it together

Let's define max_constant : exp -> int

Good example of combining several topics as we program:

- Case expressions
- Local helper functions
- Avoiding repeated recursion
- Simpler solution by using library functions

See the .sml file...

Careful definitions

When a language construct is "new and strange," there is *more* reason to define the evaluation rules precisely...

... so let's review datatype bindings and case expressions "so far"

Extensions to come but won't invalidate the "so far"

Datatype bindings

Adds type t and constructors Ci of type ti->t

Ci v is a value, i.e., the result "includes the tag"

Omit "of t" for constructors that are just tags, no underlying data

Such a Ci is a value of type t

Given an expression of type t, use case expressions to:

- See which variant (tag) it has
- Extract underlying data once you know which variant

Datatype bindings

- As usual, can use a case expressions anywhere an expression goes
 - Does not need to be whole function body, but often is
- Evaluate e to a value, call it v
- If pi is the first pattern to match v, then result is evaluation of ei in environment "extended by the match"
- Pattern Ci (x1,...,xn) matches value Ci (v1,...,vn) and extends the environment with x1 to v1 ... xn to vn
 - For "no data" constructors, pattern Ci matches value Ci

Recursive datatypes

Datatype bindings can describe recursive structures

- Have seen arithmetic expressions
- Now, linked lists:

Options are datatypes

Options are just a predefined datatype binding

- NONE and SOME are constructors, not just functions
- So use pattern-matching not isSome and valof

```
fun inc_or_zero intoption =
   case intoption of
    NONE => 0
    | SOME i => i+1
```

Lists are datatypes

Do not use hd, t1, or null either

- [] and :: are constructors too
- (strange syntax, particularly *infix*)

```
fun sum_list xs =
    case xs of
       [] => 0
       | x::xs' => x + sum_list xs'

fun append (xs,ys) =
    case xs of
       [] => ys
       | x::xs' => x :: append (xs',ys)
```

Why pattern-matching

- Pattern-matching is better for options and lists for the same reasons as for all datatypes
 - No missing cases, no exceptions for wrong variant, etc.
- We just learned the other way first for pedagogy
 - Do not use isSome, valOf, null, hd, tl on Homework 2
- So why are null, tl, etc. predefined?
 - For passing as arguments to other functions (next week)
 - Because sometimes they are convenient
 - But not a big deal: could define them yourself

Excitement ahead...

Learn some deep truths about "what is really going on"

- Using much more syntactic sugar than we realized
- Every val-binding and function-binding uses pattern-matching
- Every function in ML takes exactly one argument

First need to extend our definition of pattern-matching...

Each-of types

So far have used pattern-matching for one of types because we needed a way to access the values

Pattern matching also works for records and tuples:

- The pattern (x1,...,xn)matches the tuple value (v1,...,vn)
- The pattern {f1=x1, ..., fn=xn} matches the record value {f1=v1, ..., fn=vn} (and fields can be reordered)

Example

This is poor style, but based on what I told you so far, the only way to use patterns

Works but poor style to have one-branch cases

```
fun sum_triple triple =
   case triple of
    (x, y, z) => x + y + z

fun full_name r =
   case r of
   {first=x, middle=y, last=z} =>
    x ^ " " ^ y ^ " " ^ z
```

Val-binding patterns

- New feature: A val-binding can use a pattern, not just a variable
 - (Turns out variables are just one kind of pattern, so we just told you a half-truth in Lecture 1)

$$val p = e$$

- Great for getting (all) pieces out of an each-of type
 - Can also get only parts out (not shown here)
- Usually poor style to put a constructor pattern in a val-binding
 - Tests for the one variant and raises an exception if a different one is there (like hd, tl, and valOf)

Better example

This is okay style

- Though we will improve it again next
- Semantically identical to one-branch case expressions

```
fun sum_triple triple =
  let val (x, y, z) = triple
  in
          x + y + z
  end

fun full_name r =
  let val {first=x, middle=y, last=z} = r
  in
          x ^ " " ^ y ^ " " ^ z
  end
```

Function-argument patterns

A function argument can also be a pattern

Match against the argument in a function call

$$fun f p = e$$

Examples (great style!):

```
fun sum_triple (x, y, z) =
    x + y + z

fun full_name {first=x, middle=y, last=z} =
    x ^ " " ^ y ^ " " ^ z
```

A new way to go

- For Homework 2:
 - Do not use the # character
 - Do not need to write down any explicit types

Hmm

A function that takes one triple of type int*int*int and returns an int that is their sum:

A function that takes three int arguments and returns an int that is their sum

See the difference? (Me neither.) ©

The truth about functions

- In ML, every function takes exactly one argument (*)
- What we call multi-argument functions are just functions taking one tuple argument, implemented with a tuple pattern in the function binding
 - Elegant and flexible language design
- Enables cute and useful things you cannot do in Java, e.g.,

```
fun rotate_left (x, y, z) = (y, z, x)
fun rotate_right t = rotate_left (rotate_left t)
```

* "Zero arguments" is the unit pattern () matching the unit value ()